Geomagnetic Disturbances

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LONG-TERM GOALS

The dynamic changes of solar magnetic fields generate coronal mass ejections (CMEs), interplanetary shocks and southward interplanetary magnetic field (IMF) events, and geomagnetic disturbances. We seek to understand the solar causes of geomagnetic disturbances, especially how CMEs are associated with the changes of photospheric magnetic fields on both large and small scales, which characteristics of CMEs determine the duration and intensity of southward IMF events, and what function the ambient magnetic field and plasma in the heliosphere play in the formation of Bs events. We are working to develop tools that reliably forecast, from photospheric observations, the solar events and solar wind conditions that result in bad space weather.

OBJECTIVES

Our research concentrates on four specific scientific objectives:

(1) Measurement of the large-scale photospheric magnetic fields near the maximum of Solar Cycle 23.

(2) Continued improvement and evaluation of models of the solar corona and the solar wind.

(3) Searching for the causes of coronal mass ejections and southward IMF events.

(4) Clarification of the interrelationship between the photospheric field patterns, the emergence and redistribution of magnetic flux, solar activity, and solar cycle.

APPROACH

We are extending the 27-year time series of uniform solar magnetic field measurements by operating the Wilcox Solar Observatory (WSO) here at Stanford. We distribute both preliminary and archival WSO data sets rapidly and conveniently to other researchers, often by the end of observing day. To facilitate predictions, a variety of data products are made conveniently available via WSO’s world wide web site at http://quake.stanford.edu/~wso and by e-mail and anonymous ftp.

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14. ABSTRACT
The dynamic changes of solar magnetic fields generate coronal mass ejections (CMEs), interplanetary shocks and southward interplanetary magnetic field (IMF) events, and geomagnetic disturbances. We seek to understand the solar causes of geomagnetic disturbances, especially how CMEs are associated with the changes of photospheric magnetic fields on both large and small scales, which characteristics of CMEs determine the duration and intensity of southward IMF events, and what function the ambient magnetic field and plasma in the heliosphere play in the formation of Bs events. We are working to develop tools that reliably forecast, from photospheric observations, the solar events and solar wind conditions that result in bad space weather.

15. SUBJECT TERMS

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We continually monitor the data quality by evaluating long-term trends and by following the evolution of the solar cycle. We continually produce and distribute daily synoptic charts. We produce a variety of synoptic frames used in others' analyses. We collaborate with other researchers, including ONR-sponsored investigators Sheeley and Wang at NRL and Pizzo and Arge at SEL in Boulder, to get the most out of the data and analysis.

WORK COMPLETED

We have measured the solar magnetic field near the sunspot maximum of solar cycle 23. In the period between 01 October 2001 and 30 September 2002, we obtained 329 magnetograms for 246 distinct days, and magnetic mean field was measured on 305 days.

We have also recalibrated WSO data acquired between November 2000 and July 2002, in which the data appear to be bad due to a series of problems with phototubes and electronics. Failure of a phototube in November 2000 started malfunction of the instrumentation. Following were problems with numbers of aging electronic elements. We dedicated much more effort in the past years to diagnose and fix those problems, and maintained the instrumentation acquiring solar data. Though the data appear to be bad, we notice that the features in the magnetograms rotate nicely from day to day and the character of the intensity and doppler data plots for individual scans look normal. This suggests a possibility to re-calibrate those questionable data. Those questionable data have been eventually recalibrated based on simulation of the process of WSO observation from corresponding SOHO/MDI magnetograms.

With reference to WSO data, we have developed an algorithm for correction of 'offset' in SOHO/MDI magnetograms. The mean field and synoptic frame from corrected magnetograms have shown to be significantly improved.

We continued our effort toward understanding of solar coronal structure, solar wind and causes of coronal mass ejections. We have shown that the magnetic neutral line computed at 14 solar radii (near the Alfven critical point) should be more representative of the heliospheric current sheet; we have found that the central positions of the frontside full halo CMEs are mostly located under the coronal streamer belt.

RESULTS

We have published a study that shows magnetic neutral lines in interplanetary space (Zhao, Hoeksema, & Rich, 2002). By employing our three-layer current sheet-source surface field model (Zhao and Hoeksema, 1995), we found that the magnetic neutral line computed at 14 solar radii (near the Alfven critical point) should be more representative of the heliospheric current sheet.

In a paper accepted by JGR (Zhao, Plunkett and Liu, 2002), we suggest a 'cone' model to reproduce the halo coronal mass ejections that have constant angular width and radial velocity. In this way, the geometric properties and kinematic properties of the CMEs can be determined. These properties are important for prediction of the geoeffectiveness of a halo CME.

We have another paper accepted by JGR (Zhao & Webb, 2002) which studied all frontside full halo coronal mass ejections during the first half of solar cycle 23 to search for the possibility for prediction of geomagnetic storms. We found that the central positions of the frontside full halo CMEs are mostly

located under the coronal streamer belt. This in turn suggests that most full halo CMEs originate in the coronal helmet streamers that are sandwiched between coronal holes having opposite magnetic polarity. This finding and the solar cycle evolution of the inclination of the heliospheric current sheet may be used, at least partially, to understand the cause of the solar cycle effect on the storm-effectiveness of frontside full halo CMEs. We have submitted a work to Solar Physics (Liu, Zhao, & Hoeksema, 2002), which describes an algorithm to remove ‘offset’ in SOHO/MDI magnetograms, with reference to WSO observation. This method is now routinely used in SOHO/MDI data processing.

IMPACT/APPLICATIONS

It is suggested that the duration and intensity of magnetic cloud Bs events are on the basis of the eight characteristic parameters of magnetic clouds (Zhao, Hoeksema and Marubashi, 2001), and the most important are the orientation and strength of the clouds’ central axial field, and the bulk velocity and size of the clouds. While the first two can be determined from our previous work (Zhao, Hoeksema and Marubashi, 2001), the geometric and kinematic properties of the halo CMEs can be also determined from our ‘cone’ model (Zhao, Plunkett and Liu, 2002). With a combination of those two pieces of work, we might be able to propose a model to predict Bs events (see Figure 1).

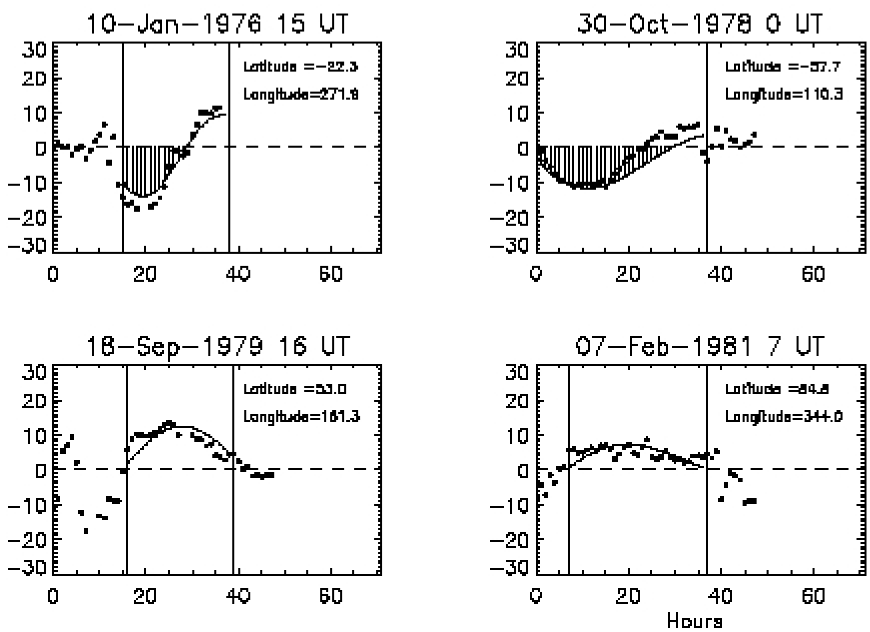

Figure 1: Comparison of the computed north-south component of magnetic field (the solid curve) with the observed north-south component (the dotted curves). The shaded areas are magnetic cloud Bs events.

TRANSITIONS

Observations are used to make monthly predictions of solar wind speed (by N. Sheeley at NRL) using WSO and other solar data sources. Based on the updated daily global photospheric magnetic field

provided by WSO and the models developed here and elsewhere, the daily prediction of solar wind speed, interplanetary magnetic field polarity, and the location of coronal holes are provided by N. Arge and V. Pizzo at the Rapid Prototyping Center at SEC in Boulder. Daily solar magnetic mean field values are also provided to the Solar Forecast Center in Boulder.

RELATED PROJECTS

Operation of the Wilcox Solar Observatory is supported in roughly equal measures by NASA, NSF and ONR.

Our group is responsible for the SOI/MDI on SOHO and progress on our scientific objectives will benefit from analysis of MDI and other SOHO data. Such direct comparisons are being supported by NASA funds.

Collaborations with other observers and modelers increase our understanding of the whole solar terrestrial system. In addition to other ONR sponsored researchers (Pizzo and Arge; Sheeley and Wang) mentioned above, we participate in space-weather-forecasting projects which are funded by the Department of Defense (DoD) through a MURI (Multiple-disciplinary University Research Initiative) grant to the University of California at Berkeley and the University of Michigan, and funded by National Science Foundation (NSF) through a CISM (the Center for Integrated Space Weather Modeling) grant to Boston University. We are also involved in the investigation of changing coronal field configurations by J. Luhmann at UC Berkeley, the development of MHD models of the coronal field by Mikic and Linker of SAIC in San Diego and S. T. Wu of UAH in Huntsville. Other projects are indicated by co-authorship in the publication list.

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